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Os Intermetatarseum: A Heritable Accessory Bone of the Human Foot

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ABSTRACT The os intermetatarseum is a relatively common accessory bone of the human foot located at the tarsometatarsal border between the first and second metatarsals. It can occur as an independent ossicle or as an osseous spur projecting from the proximal ends of the first two metatarsals, or the distal end of the first cuneiform. To determine the frequency of this congenital defect in native North American groups and East Asians from Japan, the skeletons of 846 Native Americans and 125 modern Japanese and Ainu were examined for the presence of the os intermetatarseum. The North American skeletons are from archaeological sites in various parts of Canada and the United States, including the Arctic coast, the Subarctic, the Aleutian Islands, the Northern Plains, the Illinois River area, and the Southwest. Overall frequencies ranged from no occurrence among the Arctic samples to 8% of individuals from Pecos Pueblo. Second metatarsal spurs occurred in particularly high frequencies among American Indians, whereas the East Asians were only found to have os intermetatarseums associated with the first cuneiform. Because pedigrees have shown the os intermetatarseum to be an inherited defect, its high frequency among some Native Americans may be due, in part, to a higher degree of genetic relatedness among the individuals in the North American samples than among the relatively modern East Asians. Am J Phys Anthropol 107:199–209, 1998.

One of the more common developmental defects of the human foot skeleton is an accessory bone called the os intermetatarseum (Pfitzner, 1896; Sarrafian, 1983). Also known as the os intermetatarsale I, this bone lies superiorly at the tarsometatarsal border in the space between the first and second metatarsals and is bounded proximally by the superior distolateral corner of the first cuneiform (Fig. 1). Like many accessory bones, the os intermetatarseum can occur in surprisingly high frequencies in some populations, yet usually goes unnoticed because the bone itself lacks a distinctive morphology. However, because the os intermetatarseum often occurs in articulation with the first cuneiform, the first metatarsal, or the second metatarsal (Pfitzner, 1896) and because it sometimes fuses to one of these three bones (Dwight, 1907; Pfitzner, 1896; Sarrafian, 1983), it is often readily identifiable even in archaeological samples.

The os intermetatarseum can be divided into three basic types—free-standing, articulating, and fused. A free-standing intermetatarseum is a completely independent ossicle

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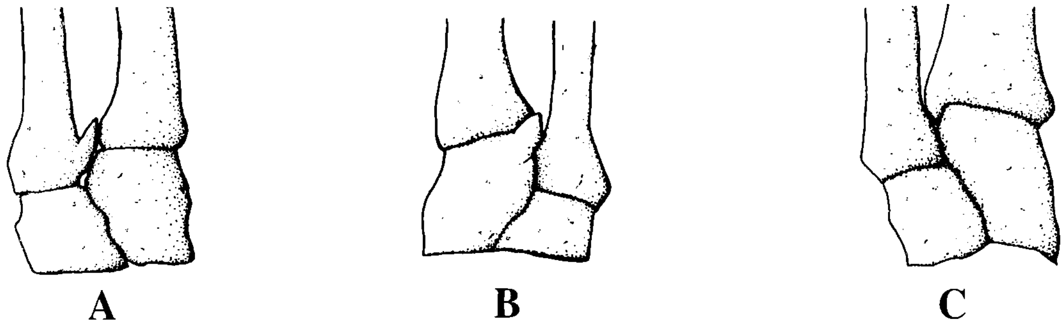

Fig. 1. Location of the os intermetatarseum in each of its three fused forms: (**A**) medially at the base of the second metatarsal (left foot), (**B**) at the dorsal distolateral corner of the first cuneiform (right foot), and (**C**) as a small hook at the lateral base of the first metatarsal (left foot).

with no osseous or articular connections to any of its three neighbors. Being completely independent, free-standing intermetatarseums leave little evidence of their presence on the primary bones of the foot and would be difficult to identify in skeletal collections. Articulating intermetatarseums exhibit an articulation with the first metatarsal, the second metatarsal, or the first cuneiform. This articulation is often by means of a synovial joint (Pfitzner, 1896; Reichmister, 1980; Scarlet et al., 1978), and simultaneous articulations with two—or even all three—of these bones is possible (Pfitzner, 1896). Therefore, the presence of an articular surface for the os intermetatarseum on the first metatarsal, the second metatarsal, or the first cuneiform allows identification of the condition in the absence of the ossicle itself.

The third and rarest type of intermetatarseum is the fused form (Pfitzner, 1896). Fused intermetatarseums are divided into three subtypes based on whether they are fused to the first metatarsal, the second metatarsal, or the first cuneiform. These forms will be referred to hereafter as first metatarsal spurs, second metatarsal spurs, and first cuneiform spurs, respectively. Despite being relatively rare, the fused forms are by far the most easily recognizable in skeletal series, because they tend to form large, osseous projections directed into the space between the first and second metatarsals (Fig. 2).

Fig. 2. Bilateral second metatarsal spurs in a skeleton from the Cibola Survey, New Mexico.

PREVIOUS STUDIES

The os intermetatarseum was first described by Wenzel Gruber in 1852 (Pfitzner, 1896). Subsequent anatomical investigation aimed at understanding the nature and frequency of this and other accessory bones demonstrated the importance of the os intermetatarseum as a relatively common skeletal variant (Dwight, 1907; Pfitzner, 1896). Among these anatomical studies, Pfitzner's is by far the most comprehensive (Pfitzner, 1896). He dissected 520 feet representing 313 cadavers and noted the presence of all

TABLE 1. Breakdown of os intermetatarseum data by sample and compared with Pfitzner

Sample name	Sample (n)	Fused and articu-lating all bones (%)	Fused and articu-lating MT2 only (%)	Fused, all bones (%)	Fused, CF1 only (%)	Fused, MT1 only (%)	Fused, MT2 only (%)	Articulating, MT2 (%)	Observer
Ainu	24	4.2	4.2[1]	0.0	0.0	0.0	0.0	4.2	Case (1996)
Modern Japanese	101	2.0	0.0	2.0	2.0	0.0	0.0	0.0	Case (1996)
Subtotal (Japan)	125	2.4	0.8	1.6	1.6	0.0	0.0	0.8	
Mobridge	73	N/A	N/A	6.8	0.0	0.0	6.8	N/A	Case (1996)
Sully	44	N/A	N/A	0.0	0.0	0.0	0.0	N/A	Case (1996)
Pecos Pueblo	163	N/A	N/A	N/A	N/A	N/A	8.0	N/A	Burnett
Subtotal (sites)	280	N/A	N/A	4.3	0.0	0.0	6.4	N/A	
Arctic	150	N/A	0.0	N/A	N/A	N/A	0.0	0.0	Ossenberg
Subarctic	164	N/A	0.6	N/A	N/A	N/A	0.6	0.0	Ossenberg
Aleutian Islands	66	N/A	4.5	N/A	N/A	N/A	4.5	1.5	Ossenberg
Northern Plains	36	N/A	2.8	N/A	N/A	N/A	0.0	2.8	Ossenberg
NE Plains Periphery	92	N/A	7.6	N/A	N/A	N/A	5.4	2.2	Ossenberg
Illinois	58	N/A	5.2	N/A	N/A	N/A	3.5	1.7	Ossenberg
Subtotal (regional)	566	N/A	2.7	N/A	N/A	N/A	1.9	0.9	
Total (all samples)	971	2.4	2.3	2.9	0.8	0.0	3.0	0.9	
Pfitzner's Germans	313	10.2	N/A	2.9	1.6	0.6	0.6	N/A	

[1] CF1 of this and the opposite foot are affected.

accessory bones encountered, including the os intermetatarseum. In all, 39 individuals (12.5%) were found to exhibit at least one os intermetatarseum (Table 1). Thirteen were bilaterally affected, 16 were unilaterally affected, and in 10 cases laterality was indeterminate because only one of the feet was examined. Pfitzner found the most common expression of the os intermetatarseum to be the articulating form (Pfitzner, 1896). In 64% of those affected (n = 25), the intermetatarseum articulated with one or more of the three bones surrounding it in at least one foot. In 23% (n = 9), the intermetatarseum was completely free-standing in at least one foot. In another 23% (n = 9), the intermetatarseum was fused to either the first cuneiform (five individuals), the first metatarsal (two individuals), or the second metatarsal (two individuals) in at least one foot.

The 13 bilaterally affected individuals provide some insight into the relationship between the fused and unfused forms of the condition. Fifty-four percent (n = 7) exhibited an articulating os intermetatarseum in both feet. Fifteen percent (n = 2) had an articulating intermetatarseum in one foot and a completely free-standing intermetatarseum in the other. Another 15% (n = 2) had an articulating intermetatarseum in one foot and a fused intermetatarseum in the other. Only single examples of bilaterally free-standing and bilaterally fused intermetatarseums were described. The bilaterally fused intermetatarseums were in the form of second metatarsal spurs. These data suggest that the free-standing, articulating, and fused forms of the os intermetatarseum are all interrelated and should be treated as part of a single condition. The only form not found by Pfitzner to be associated with any other form was first metatarsal spurs.

Pfitzner identified only two examples of first metatarsal spurs in his study, both of which were unilateral. Because bilateral examples were not identified, one might suspect that first metatarsal spurs are a different condition from the rest of the intermetatarseum complex, perhaps caused by ossification of the accessory tendinous arch of the first dorsal interosseous muscle, as suggested by Schinz et al. (1951). However, at least one study has demonstrated a relationship between the first metatarsal spur and an unfused intermetatarseum in the feet of a single individual, suggesting a definite relationship between first metatarsal spurs and the rest of the os intermetatarseum complex (Tsuruta et al., 1969).

Many other studies of the os intermetatarseum followed that of Pfitzner, the majority relying on radiographic analysis (Geist, 1914–15; Holland, 1928; Shands, 1931; O'Rahilly, 1953; Shands and Wentz, 1953) (see Table 3). These studies illustrate a clear inconsistency between os intermetatarseum

frequencies resulting from anatomical and radiographic studies. Generally, anatomical studies suggest very high frequencies of 8–14% for the os intermetatarseum, whereas radiographic studies—with rare exceptions—tend toward frequencies of less than 2%. This disparity can probably be attributed to the position of the os intermetatarseum within the foot, because this bone is said to be difficult to diagnose properly in standard radiographic views (Dwight, 1907; Geist, 1914–15; Holland, 1928).

Some difference of opinion also exists about whether the os intermetatarseum occurs most commonly in its free or fused form (Pfitzner, 1896; Dwight, 1907; Holland, 1928; O'Rahilly, 1953; Henderson, 1963). Dwight (1907) reports in his anatomical study of accessory bones that the os intermetatarseum is usually found as a first cuneiform spur. In contrast, Pfitzner (1896) found fused intermetatarseums in only 19% of affected individuals and articulation between the intermetatarseum and one of its neighbors in 64%. Radiologists tend to concur with Pfitzner, usually reporting the os intermetatarseum in its unfused form (Geist, 1914–15; Shands, 1931; O'Rahilly, 1953).

Etiology

Today there exist two main hypotheses to explain the origin of the os intermetatarseum. The first is that the os intermetatarseum represents a true accessory bone (Pfitzner, 1896). This hypothesis is the most commonly cited one but is problematic because the various forms of the intermetatarseum are not adequately explained by the normal definition of an accessory bone. Jones (1944) defines accessory bones as ". . . normal parts or prominences of the ordinary tarsal bones that are abnormally separated from the main elements . . ." but not due to fracture. This definition appears to adequately describe most of the more common accessory ossicles but fails to account for certain traits of the os intermetatarseum. For example, the intermetatarseum is not exclusively associated with the tarsals. Furthermore, it cannot really be identified as a normal part or prominence of any of its three neighbors, because it can be found associated with any one of them or with all three simultaneously. Such problems raise questions about the classification of the os intermetatarseum as a true accessory bone.

The competing hypothesis holds that the os intermetatarseum represents a supernumerary metatarsal and is therefore a form of central polydactyly (Henderson, 1963; Paul and Juhl, 1972; Christensen et al., 1981). The rationale behind this explanation can probably be attributed to a similarity in the location of second metatarsal spurs and supernumerary second metatarsals. Shands and Wentz (1953) present a radiograph of a supernumerary metatarsal projecting medially from near the base of a second metatarsal and identify it as an os intermetatarseum because of its location. However, other than this positional similarity, there appears to be little evidence to support a connection between the os intermetatarseum and polydactyly. For example, in the Shands and Wentz radiograph, the shape of the supernumerary digit is similar to that of other metatarsals, whereas the shapes of bones generally identified as intermetatarseums are quite variable and do not in any way resemble metatarsals (Pfitzner, 1896; Dwight, 1907). Furthermore, supernumerary digits are usually found either as free structures near the base of one of the metatarsals or as structures projecting from the shaft of one of the metatarsals. Because the os intermetatarseum may also be found as a first cuneiform spur, it appears unlikely that the os intermetatarseum and central polydactyly are equivalent defects. Finally, the developmental pattern of the os intermetatarseum is quite different from that of the metatarsals. If the intermetatarseum were indeed simply a severely hypoplastic supernumerary metatarsal, one would expect the onset of ossification to be similar to that of the other metatarsals, occurring at around 10 weeks in utero (Gardner et al., 1959). By contrast, Trolle (1948) noted several examples of cartilaginous intermetatarseums in fetuses older than 14 weeks of age, and several children exhibiting cartilaginous os intermetatarseums after birth have also been reported (Pfitzner, 1896; Holland, 1928). These observations suggest that the intermetatarseum does not ossify along with the digital bones during the prenatal period, but

rather ossifies postnatally as do the majority of the tarsals (Francis and Werle, 1939). In fact, Scarlet et al. (1978) state that the intermetatarseum does not ossify until at least age 2 in females and age 3 in males. This timing corresponds with that of the primary ossification centers in the cuneiforms and navicular (Francis and Werle, 1939).

Perhaps the best way to explain the variability in the location of the os intermetatarseum and in its interaction with its three neighbors is to consider a possible model for this behavior in an accessory bone of the human hand. The third metacarpal styloid process initially develops from the carpal mesenchyme as a completely free-standing ossicle known as the os styloideum (O'Rahilly, 1953). This ossicle normally fuses to the base of the third metacarpal later in the development process. In some cases, however, the os styloideum remains free-standing, and in other cases it may even fuse to the neighboring capitate or trapezoid (O'Rahilly, 1953). The same might be true for the os intermetatarseum. It may be a product of the tarsal mesenchyme, developing from the tarsal mass at a position adjacent to the superior distolateral corner of the first cuneiform. As cavitation proceeds within the foot, this ossicle may fail to separate from the first cuneiform in some instances, leading to a first cuneiform spur. Perhaps under other circumstances, the ossicle fuses after cavition during the process of chondrification, as does the os styloideum and the hamulus of the hamate (O'Rahilly, 1953).

One final complicating factor in understanding the etiology of the os intermetatarseum is its variable association with certain tendons and ligaments. Friedl (1924) believed that some forms of the os intermetatarseum function as pseudosesamoids because of their location just plantar to the tendon of the first dorsal interosseous muscle as it arises from the superior distolateral corner of the first cuneiform. More recent surgical observations report associations with other tendons and ligaments. For example, Henderson (1963) excised second metatarsal spurs from two siblings and found ". . . a tendinous structure extending from each [second metatarsal] spur to the base of the proximal phalanx of the great toe, to which it was attached on the dorsolateral aspect." In one patient, the tendon was found to pass through the belly of the dorsal interosseous muscle on its way to attachment with the first proximal phalanx. These data suggested to Henderson that the metatarsal spurs and tendons might represent a lost first plantar interosseous muscle. Yet another physician excised an os intermetatarseum that was attached via cartilage to the dorsal ligaments of the first metatarsocuneiform and the second metatarsal-first cuneiform joints along its superior surface, and to the interosseous ligaments of the first cuneiform-second metatarsal and the first cuneiform-first metatarsal bases on its inferior surface (Scarlet et al., 1978). However, the infrequent reporting of associations between the intermetatarseum and the ligaments and tendons of the first intermetatarsal space, coupled with their variable description when they are reported, suggests that these observations are probably of minimal etiological significance.

Heritability

Any explanation concerning the origin of the os intermetatarseum must take into account information about genetic inheritance of the condition. Two pedigrees have been published thus far suggesting genetic inheritance of second metatarsal spurs (Waters, 1958; Henderson, 1963). The smaller pedigree involves two brothers and a sister, each with bilateral os intermetatarseum spurs projecting medially from the bases of their second metatarsals. In two of these children, the spurs were large enough to cause the pathological condition known as hallux valgus, characterized by lateral displacement of the big toe such that the distal end of the first metatarsal becomes prominent along the medial side of the foot. Surgical resection of the intermetatarseum spurs in the older brother and sister demonstrated bilateral fusion in the brother but only unilateral fusion in the sister. The unfused intermetatarseum articulated with the second metatarsal by means of a synovial joint (Henderson, 1963). The parents of these children were examined and found to be unaffected, although Henderson does not

state whether examination was by palpation or radiography. This small pedigree suggests that the os intermetatarseum is to some extent an inherited structure and lends further support to Pfitzner's observation that fused and unfused forms of the os intermetatarseum are generally part of a single phenomenon.

The larger pedigree extends over three generations. It involves a grandmother, her two daughters, and their seven children (Waters, 1958). As was the case with Henderson's pedigree, this one involves an os intermetatarseum fused to the medial base of the second metatarsal. The grandmother of the pedigree exhibited the os intermetatarseum bilaterally, as did both of her daughters, one of whom was the proband. The proband had given birth to four children at the time of the study. Her 7-year-old daughter and 6-year-old son both exhibited the condition radiographically; a second daughter (only 18 months old) was listed as possibly affected, and a 6-month-old daughter was unaffected. The proband's sister had three boys, ages 7, 6, and 3, none of whom exhibited the os intermetatarseum, although it was thought that the oldest son might have shown a hint of the condition in his radiographs. Altogether, 50% of the individuals in this pedigree were affected, a frequency often suggestive of dominant inheritance. If the younger children would have been evaluated as they grew older, it is possible that some of them might have later exhibited a diagnosable form of the condition as the bones of their feet continued to ossify. Unfortunately, no information about the children's fathers was available.

PURPOSE OF THIS STUDY

Little is known about the distribution of the os intermetatarseum in archaeological skeletal series. Despite being one of the most common developmental defects of the human foot skeleton (Pfitzner, 1896), a search of the literature produced only a single publication noting an os intermetatarseum in an archaeological sample (Anderson, 1963). In it, the intermetatarseum was described simply as an osteophyte but was readily identifiable as a second metatarsal spur in the accompanying photograph. However, despite infrequent reporting in the literature, the incidence of fused os intermetatarseums appears to be quite high in some native North American groups. This article reports on the frequency and variable expression of the os intermetatarseum in several skeletal samples from North America and Japan.

MATERIALS AND METHODS

The foot bones of 846 Native American (Indian and Eskimo) skeletons from archaeological sites in North America and of 125 Ainu and modern Japanese skeletons from Japan were scored for the presence of an os intermetatarseum (Table 1). Data from the Native Americans are reported by site for the larger samples and by region for samples composed of skeletons from several small sites. Data for the samples from Japan are reported by cultural affiliation.

For the Mobridge and Sully sites in South Dakota, the first metatarsal, second metatarsal, and first cuneiform were scored for fused intermetatarseums only. For the regional sites, both fused and articulating forms were scored but only on the second metatarsal. For the Pecos Pueblo sample from New Mexico, only fused forms found on the second metatarsal were scored. For the two samples from Japan, the first metatarsal, second metatarsal, and first cuneiform were scored for both the articulating and fused forms.

The largest sample from a single site comes from the Pecos Pueblo in New Mexico and represents skeletons dating from the late prehistoric through the early historic period (Hooton, 1930). The other two single site samples come from Mobridge and Sully, both protohistoric Arikara sites from different parts of South Dakota. The Mobridge site (39WW1) is associated with three cemeteries. Skeletons analyzed for this study come primarily from Feature 2 and date to the first half of the 18th century (Merchant and Ubelaker, 1977; Owsley et al., 1982). The Sully site (39SL4) is associated with four temporally distinct cemeteries spanning from AD 1600–1750 (Owsley and Jantz, 1977).

Dates for the regional samples are as follows: Arctic coast, including both Alaska

and Canada (AD 1000–1900); Subarctic, including Alaska, Canada, Kodiak Island, and the North Pacific Coast (1500 BC–AD 1900); Aleutian Islands (2000 BC–AD 1700); Northern Plains (AD 1700–1900); Northeastern Plains Periphery (AD 500–1700); and Illinois River (100 BC–AD 100).

The modern Japanese skeletons come from late 19th and early 20th century Japanese cadavers and exhibit well-preserved foot skeletons that are nearly all intact. The Ainu skeletons were excavated in the latter half of the 19th century and are of uncertain date.The foot skeletons of the Ainu sample were poorly preserved, allowing only 24 of 95 individuals to be scored.

Presence of the os intermetatarseum was scored as follows. Second metatarsal spurs were defined by the presence of a flat, rectangular wing of bone situated superiorly and projecting at approximately a 30° angle medially from the anterior portion of the second metatarsal base (Fig. 2). First metatarsal and first cuneiform spurs were defined by an abnormal projection of the anterior superolateral corner of the first cuneiform, or an extension of the lateral side of the first metatarsal near the base (Fig. 1). Articulating intermetatarseums were scored when a distinct articular facet was present at the same location where one would expect to find an intermetatarseum spur. This location would be on the superolateral side of the first metatarsal slightly distal of the proximal facet, on the superomedial side of the second metatarsal several millimeters distal to the proximal facet, and at the superior distolateral corner of the first cuneiform.

Because the ossification timing of the os intermetatarseum has not been conclusively determined, it is not clear when the os intermetatarseum becomes fully ossified. To increase the liklihood that any os intermetatarseums would be fully ossified, all samples were limited to individuals whose digital epiphyses had already begun to fuse. This limitation effectively restricts the samples to individuals 13 years of age and older for females and 15 years and older for males (Greulich and Pyle, 1959).

Os intermetatarseum frequencies were calculated by dividing the number of individuals affected by the total number of individuals examined. An individual is defined as any discrete skeleton possessing at least one scorable bone of the appropriate type. The number of individuals is used rather than the number of feet affected to make the data comparable with previous radiographic and anatomical studies as well as to allow consideration of defect laterality and genetic implications.

Os intermetatarseum frequencies in the various samples were compared using a two-tailed Fisher's exact test. In each case, the null hypothesis (H_0) is that the two samples have the same frequency, and the alternative hypothesis (H_a) is that the frequencies are different. Significance was tested at an alpha level of 0.05. Results of these tests are given in the form of a *P* value following discussion of each comparison.

RESULTS

By far the most common intermetatarseum type found among the American Indian and Eskimo samples was second metatarsal spurs (Table 1). Frequencies for these samples range from no occurrence in 150 individuals from the Arctic coast to 8% of 163 individuals from the Pecos Pueblo. The mean frequency for all skeletons, including the two samples from Japan, is 3.0%. Bilaterality of the defect is found in 70% of affected skeletons with both second metatarsals present (Table 2), although in three of these cases the opposite foot exhibits an articulating rather than a fused intermetatarseum. Males are affected somewhat more frequently than females, but this difference is not significant ($P > 0.1$).

No first metatarsal spurs were found in the 242 skeletons examined for this form (Table 1). First cuneiform spurs were only found in the modern Japanese sample, affecting 2%. The single affected Ainu individual exhibited bilateral involvement of the first cuneiform but also exhibited a lesion on the second metatarsal consistent with cartilaginous or fibrocartilaginous coalition between the metatarsal and the os intermetatarseum. Similar nonosseous coalitions between an accessory bone and a primary bone of the foot have occasionally been reported in the literature (Pfitzner, 1896; Sarrafian, 1983).

TABLE 2. Breakdown of MT2 os intermetatarseum data by sample

Sample	Sample (n)	MT2s (left/right)	% Individuals affected	% Feet affected	Bilateral	Unilateral	Laterality unknown
Ainu	24	17/20	4.2	2.7	0	1[1]	0
Modern Japanese	101	98/97	0.0	0.0	0	0	0
Mobridge	73	76/74	6.8	4.7	2	2	1
Sully	44	38/31	0.0	0.0	0	0	0
Pecos Pueblo	163	Not recorded	8.0	6.9	6	0	7
Arctic	150	123/117	0.0	0.0	0	0	0
Subarctic	164	128/136	0.6	0.4	0	1	0
Aleutian Islands	66	56/58	4.5	4.4	2	0	1
Northern Plains	36	32/33	2.8	3.1	1	0	0
NE Plains Periphery	92	71/65	7.6	6.6	2	2	3
Illinois	58	53/51	5.2	3.8	1	0	2
Totals	971	1374	3.5	3.5	14	6	14

[1] CF1 of this and the opposite foot are also affected.

Two of the five affected individuals from Mobridge may have experienced some degree of dysfunction due to the presence of second metatarsal spurs. Both of these skeletons exhibit fused intermetatarseums that appear to articulate with the first metatarsal. The intermetatarseum affecting the right foot of skeleton NMNH 382895 is a bit longer than the others at Mobridge, and its articulation with the first metatarsal occurs right at the edge of the proximal articular surface (Fig. 3). It is possible that this orientation would have resulted in hallux valgus, or lateral angulation of the distal portion of the first metatarsal. Examples of hallux valgus caused by the presence of an os intermetatarseum are occasionally reported (Waters, 1958; Henderson, 1963) and tend to be associated with pain while standing or walking. In some cases, the associated pain is described as severe (Waters, 1958). At least two individuals experiencing pain from an unfused intermetatarseum have also been reported (Scarlet et al., 1978; Reichmister, 1980).

Fig. 3. Right first and second metatarsals of skeleton NMNH 382895 from the Mobridge site showing articulation of the second metatarsal spur with the base of the first metatarsal.

DISCUSSION

Because the os intermetatarseum occurs in three distinct forms, only two of which have the potential to be scored in the absence of soft tissue, our data cannot be easily compared with most of the studies listed in Table 3. In fact, the only reasonable comparison is with Pfitzner's data (Table 1), because he is the only other investigator who distinguished among the fused, articulating, and free-standing forms of the condition. Breaking Pfitzner's total sample down into groups comparable to those made from our data, we find a frequency of 10.2% for individuals with articulating and fused intermetatarseums only, a frequency of 2.9% for those with one of the three fused forms, and frequencies of 1.6% for first cuneiform spurs and 0.6% for second metatarsal spurs.

The two samples from Japan show combined frequencies for the articulating and fused intermetatarseums that are between

TABLE 3. Reported os intermetatarseum frequencies in past studies (all types)

Investigator	Study type	Year	Sample (n)	Frequency (%)	Frequency basis	Source
W. Gruber	Anatomic	1852	100	8	Individual	Pfitzner (1896)
W. Pfitzner	Anatomic	1896	313	12.5	Individual	Pfitzner (1896)
T. Dwight	Anatomic	1907	??	10	Unknown	Dwight (1907)
A. Hasselwander	Anatomic	1910	110	10	Unknown	Trolle (1948)
A. Tokmakoff	Anatomic	1928	50	14	Individual	Tokmakoff (1928)
D. Trolle	Fetal anatomic	1948	250	8.0	Individual	Trolle (1948)
E. Geist	Radiographic	1914	100	0.0	Individual	Geist (1914–15)
A. Heimerzheim	Radiographic	1925	1800	0.4	Feet	Heimerzheim (1925)
M. Burman and P. Lapidus	Radiographic	1931	1000	3.3	Feet	Burman and Lapidus (1931)
A. Shands	Radiographic	1931	404	1.2	Individual	Shands (1931)
A. Faber	Radiographic	1934	1000	1.2	Individual	Faber (1934)
F. Holle	Radiographic	1938	1000	6.8	Unknown	Trolle (1948)
A. Arho	Radiographic	1940	1074	0.3	Unknown	Trolle (1948)
H. Quereilhac	Radiographic	1942	445	0.2	Individual	Waters (1958)
A. Shands and I. Wentz[1]	Radiographic	1953	850	0.1	Individual	Shands and Wentz (1953)
K. Suzuki	Radiographic	1957	701	0.4	Feet	Suzuki (1957)
T. Tsuruta et al.	Radiographic	1969	1449	1.5	Individual	Tsuruta et al. (1969)

[1] Sample primarily composed of young children.

one-half and one-fourth as high as for Pfitzner's Europeans ($P = 0.003$) (Table 1). Nearly all the difference between the German and two Japanese samples can be attributed to a lack of articulating intermetatarseums in the Japanese samples. This difference may suggest simply that the os intermetatarseum is a much less common defect among the two Japanese samples, or it may mean that the ability to score articulating forms in dry bone is reduced when compared with scoring via dissection. One factor is the comparatively small size of the Japanese samples. For the fused forms, the Japanese samples are not significantly different from Pfitzner's Europeans ($P = 0.140$).

The only other samples to be evaluated for fused intermetatarseums on all three relevant bones were the Mobridge and Sully sites. Because these two sites lie less than 100 miles apart along the Missouri River and are temporally and culturally similar, one would expect them to show similar frequencies of fused intermetatarseums, as is true of most other hand and foot defects studied at the sites (Case, 1996). Although the frequencies themselves seem quite different at first glance (6.8% versus 0.0%), this difference is not significant ($P = 0.09$), probably due to the small size of the Sully sample.

When compared with Pfitzner's Europeans, the Mobridge frequencies for second metatarsal spurs are quite high, exhibiting a frequency that is roughly 11 times greater than that of the Europeans ($P = 0.003$). Similarly high frequencies are found for many of the other Native American samples as well, with the Pecos Pueblo (8.0%, $P = 0.00003$), Aleutian Islands (4.5%, $P = 0.039$), and Northeastern Plains periphery (5.4%, $P = 0.008$) all showing frequencies at least 7 times greater than for Pfitzner's sample. Interestingly, two of the three regional samples showing second metatarsal spur frequencies lower than those found in these Europeans are the Arctic and Subarctic—the only two regions that were primarily Eskimo in background. The only non-Eskimo regional sample showing no evidence of second metatarsal spurs was the Northern Plains, but this may simply be an effect of small sample size. An interesting trend develops when combining the various samples into groups (Table 1). The single site samples exhibit a combined frequency for second metatarsal spurs that is significantly higher than even that of the regional samples ($P = 0.001$), whereas the regional samples as a whole are not significantly different from Pfitzner's Europeans ($P = 0.10$).

Perhaps the best explanation for these frequency trends is the heritability of the os intermetatarseum. Two of the three samples with the highest frequencies of affected second metatarsals are American Indian samples derived from cemeteries associated

with a single site. It is likely that a high proportion of the people buried in these cemeteries were blood relatives and that the cemetery populations shared a high degree of genetic similarity. On the other hand, Pfitzner's European sample, as well as the modern Japanese sample, are cadaver populations in which few if any of the individuals examined were probably related. Therefore, the average degree of genetic similarity between individuals in these samples is probably much lower because they are drawn from a much larger gene pool. Assuming that the Mobridge and Pecos cemeteries were used by the same families for many generations and that the trait is selectively neutral, it is easy to see how a strongly inherited defect like second metatarsal spurs, once introduced into the gene pool, could come to affect a fairly high proportion of a burial population in a few generations' time.

Combining information from this article and past studies, a somewhat different picture of the os intermetatarseum from that presented in Pfitzner's study begins to develop. Pfitzner's conclusions about the relative importance of the different fused forms of the os intermetatarseum do not hold for most of our samples, and these differences appear to correlate with the geographic origin of the samples to some extent. Our data seem to suggest that the fused form rather than the articulating form is more common among American Indians. Furthermore, whereas Pfitzner found frequencies of first and second metatarsal spurs to be the same, our data reveal that second metatarsal spurs are much more common among the Native Americans than are first metatarsal spurs. On the other hand, Pfitzner's observations about the fused form seem to be supported by the modern Japanese sample, with first cuneiform spurs being the most common. Perhaps an analysis of other European skeletal series would help determine whether the trends noted by Pfitzner are fairly universal among Europeans or are peculiar to his German sample.

CONCLUSION

The os intermetatarseum is a relatively common and occasionally painful accessory bone occurring in frequencies ranging from 0.0% to 14%. It can be associated with any one of its three neighbors through articulation or synostosis and exhibits relative frequencies at each of these locations that appear to vary somewhat by population. The fused form of the condition is easily identifiable and has been found to occur in high frequencies in some Native American skeletal series. The unfused form is sometimes identifiable skeletally by the presence of an articular facet on the first metatarsal, the second metatarsal, or the first cuneiform, but frequencies of this form in the Japanese samples are much lower than those found by Pfitzner. These frequency differences suggest that Pfitzner's sample of German cadavers exhibited abnormally high incidences of the articulating form, that the two Japanese samples exhibit unusually low incidences, or that articulating forms of the os intermetatarseum are more easily recognized by dissection than in dry bone.

The os intermetatarseum appears to be strongly inherited, at least when fused to the second metatarsal, and this heritability probably explains the unusually high frequencies of these spurs in two of the three single site samples. Such strong heritability also suggests that individuals from a single site exhibiting second metatarsal spurs have a high probability of being genetically related to one another.

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